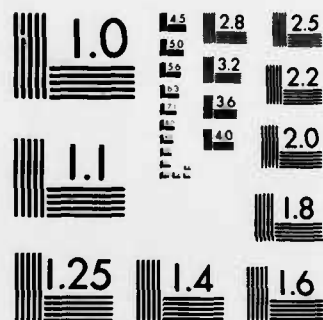


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TOWED H-MAGNETOMETER

[Zhuriy, I. G. and A. Ya. Rotshteyn, Buksiruyemyy H-Magnitometr, Geofizicheskaya Apparatura, No. 49, 1972, pp. 13-16; Russian]

Measurements of the TMF on a water surface are made with magnetometers placed in a towed "bird" behind the ship. Towed component magnetometers are currently in the design and testing stage.^{3,7} In the present paper, the authors propose a magnetometer for direct measurement of the horizontal component of the TMF with indirect stabilization of the MFE of the quantum magnetometer (with a rigid mounting of the MFE in the towed "bird").

As is well known,⁹ to measure the horizontal component of the TMF with a quantum magnetometer, it is necessary to generate a vertical auxiliary compensating field (ACF) in the Helmholtz coils (HC). If the HC and MFE are mounted on a moving object, the auxiliary field is generated by the summation of the fields of each of the three pairs of orthogonal HC whose magnetic axes are parallel to the axes of the vertical gyroscope (Fig. 1). The field strengths in each pair of HC are determined by the angles of roll θ and pitch ψ of the "bird." The angles of deflection of the object from the vertical are measured with the vertical gyroscope. The currents in the coils are calculated from the formulas given by A. Ya. Rotshteyn and I. G. Zhuriy,^{5,6}

$$\left. \begin{aligned} I_I &= U_0 k_I \cos \psi \cos \theta; \\ I_{II} &= U_0 k_{II} \sin \psi; \\ I_{III} &= U_0 k_{III} \cos \psi \sin \theta, \end{aligned} \right\} \quad (1)$$

where U_0 is the supply voltage, and k_I , k_{II} , and k_{III} are the transmission coefficients of the computing system, consisting of two sine-cosine rotary transformers (SCRT), located on the vertical gyroscope.

To generate an auxiliary field H_a equal in magnitude to the vertical component of the TMF for displacements of the towed "bird" in the latitudinal direction, it is necessary to regulate the ACF either manually or by means of an automatic compensation system.^{4,8} A modulating field according to expression (1) must be created in the volume of the gauge for the operation of the automatic compensation system.

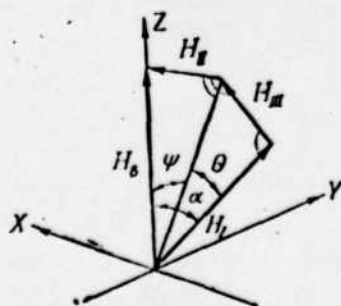


Fig. 1. Summation of vectors of HC magnetic fields

* Numbers in the right margin indicate pagination in the original text.

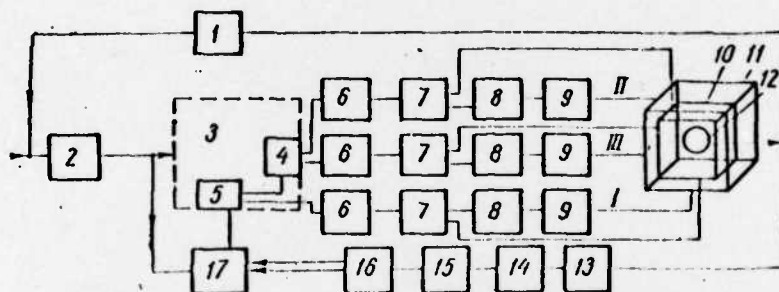


Fig. 2. Block diagram of towed II-magnetometer

To measure the horizontal component, a magnetometer was designed, a block diagram of which is shown in Fig. 2. The instrument consists of systems for generating the ACF and automatic compensation, and of a modular magnetometer itself. The supply from converter 2 is fed to vertical gyroscope 3 and a computing system consisting of two SCRT, 4 and 5. From the computing system, the signals are sent to the corresponding HC 11 via scaling transformers 6, transformers 7, phase detectors 8 and smoothing filters 9. Since the modulating field must be vertical, its generation requires three pairs of extra windings on coils 10, in which the currents are calculated with the computing system by use of formulas (1). The ac signals are rectified with full-wave phase detector 8. The automatic compensation system consists of frequency detector 13, filter of the first harmonic 14, amplifier 15, and servo motor 16 for regulating U_0 ; H and T are measured with MFE 12; SCRT 17 is used for the adjustment of U_0 . The signal from MFE 12 is fed to the towing ship via electronic block 1. The currents for each pair of coils are calculated from three channels: channel I converts the signals fed to the vertical coils, and channels II and III convert those fed to the horizontal coils. /14

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Let us calculate the error involved in the generation of the ACF.

In Fig. 1, angle α is the angle of deflection of the vertical axis of the towed "bird" from the vertical

$$\alpha = \arccos \frac{H_I}{\sqrt{H_I^2 + H_{II}^2 + H_{III}^2}}. \quad (2)$$

The quantities H_I , H_{II} , and H_{III} include the coefficients k_I , k_{II} , and k_{III} , /15
determined with the errors

$$\left. \begin{aligned} k_I &= k_1 k_3 k_4 n_{I1} f_{I1} A_I \frac{1}{R_{H I}}, \\ k_{II} &= k_1 k_3 k_2 n_{II1} f_{II1} A_{II} \frac{1}{R_{H II}}, \\ k_{III} &= k_1 k_3 k_5 k_6 n_{III1} f_{III1} A_{III} \frac{1}{R_{H III}}, \end{aligned} \right\} \quad (3)$$

where k_1 is the transmission coefficient of the SCRT used to adjust the ACF of the automatic compensation system; k_2 , k_3 , k_4 , and k_5 are the transformation coefficients

of the scaling transformer in channel II (see Fig. 2), SCRT 3, SCRT 4 and scaling transformer in channel 3, respectively; n_I , n_{II} , and n_{III} are the transformation coefficients of transformers 7; f_I , f_{II} , and f_{III} are the transmission coefficients of the phase detectors; A_I , A_{II} , and A_{III} are the constants of HC.

Using formulas (1)-(3), we find the mean square error of angle α (Ref. 2)

$$\sigma_\alpha = \frac{\cos \psi \cos \theta}{\sqrt{1 - \cos^2 \psi \cos^2 \theta}} \sqrt{\left(\frac{1 - \cos^2 \psi \cos^2 \theta}{r_I + R_{HI}} \Delta r_I \right)^2 + \dots + \left(\frac{\sin^2 \psi}{r_{II} + R_{HII}} \Delta r_{II} \right)^2 + \left(\frac{\cos^2 \psi \sin^2 \theta}{r_{III} + R_{HIII}} \Delta r_{III} \right)^2 + \dots + (\tan \psi \cdot \Delta \psi)^2 + (\tan \theta \cdot \Delta \theta)^2}, \quad (4)$$

where r_I , r_{II} , and r_{III} are the resistances of the triodes in the conducting state of channels I, II, III.

Substituting for SCRT of class A the mean square error $\Delta \psi = \Delta \theta = 0.00007$ rad, $r_I = r_{II} = r_{III} = 8$ ohm, $\Delta r = 0.1$ ohm, $k_2 = 0.53$ and $k_5 = 0.98$, we obtain σ_α for different values of the angles of roll and pitch:

$\psi = \theta$, deg	1	5	10	15
σ_α , min	0.24	0.27	0.35	0.44.

Preliminary tests of the magnetometer showed that when the coil system deflected from the vertical by 10° , the ACF deflected by an angle of about $1'$.

The chief advantage of the proposed magnetometer is the absence of mechanical loads on the gyrosystem; this makes it possible to use a quantum magnetometer and avoid increasing the dynamic errors of the vertical gyroscope, and allows the MFE to be located at any distance from the vertical gyroscope. By using the magnetometer, H may be measured directly with a rigidly mounted MFE in the towed "bird."

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